Effects of the Temperature on the Development of Pieris brassicae, L.

By ORAZIO QUERCI.

My wife, who since 1896 has followed the joys and sorrows of my entomological "game," reared the larvae, observing their lives.

I. Records Concerning the Development in Portugal.

(1) In November and December, 1932 (mean temperature 55° to 60° F.) some *Pieris brassicae*, L. were on the wing laying eggs.

(2) On 16th December we took a cabbage with more than a hundred larvae, which we reared in cages. At the beginning of January (max. 59°, min. 46°) those larvae grew and matured slowly.

(3) Only six larvae, kept in direct sunshine, pupated with difficulty from 2nd to 5th January (max. 58°, min. 50°).

(4) All the other larvae died from the attacks of *Microgaster glomeratus*, L.

(5) From January to 6th March (rarely max. 60°) no pupae emerged. On 7th and 9th March (max. 60° to 63°) two pupae produced males and both sexes emerged on the 13th and 15th (max. 64°, min. 50°). In the country, in spite of the parasites, a large emergence occurred from 5th February to 13th April and some worn adults flew until the 21st.

(6) From 8th February to 11th March we put into cages, with florid food-plants, some females which laid a few eggs, but these did not hatch although the weather was fine. On 12th March a female laid many eggs both in the morning (50°) and afternoon (55°). From 13th to 19th the maximum varied between 56° and 64°; on the 20th (max. 67°) the eggs turned dark and on the 21st (63° to 70°) they hatched gradually during the whole day.

(7) The larvae had hatched by day but not at the same time and they stopped, to change their skin, at different hours of each day on which they moulted. From 22nd to 30th March the daily temperature varied between 63° and 49°, being over 55° from about 10 a.m. to 4 p.m., and in this period the larvae moulted in a few hours.

(8) Other larvae, which commenced to moult after 2 p.m., were caught by the cold before they had time to change and remained dormant until the day following. From the longer pause without feeding they grew less than the others of the same batch.

(9) On 31st March (66°) the larvae were very active and those, which, not becoming dormant, had grown more rapidly, became full-fed.

(10) On 1st April it was about 54° for the whole day and the larvae which matured became dormant. They hung up on the 3rd (70°) but needed two days to form brown pupae.

(11) Most larvae, which matured on 3rd to 6th April (above 65° for several hours every day), hung up at once and formed green pupae in a few hours.

(12) From 2nd to 6th April, 53 both green and brown chrysalids were formed in our cages.

(13) The bright green pupae which were formed rapidly on 5th April (max. 71°) emerged on the 20th and 21st while other green pupae, formed more slowly on the 2nd (64°), produced adults on the 23rd.

(14) From 20th to 23rd April (max. 70°, min. 49°) 19 green pupae emerged at home. On the 24th it was 75° with high vapour pressure and any emergence ceased for a week. The last six green chrysalids in our cages produced adults at the beginning of May when the maximum decreased to 62°. From 6th to 11th May, although the climate was suitable, no other *brassicae* emerged from the brown pupae which had remained in our cages. Afterwards it was very hot.

(15) On 20th May we went to Spain where the brown pupae emerged from 14th September to 12th October, after that the intense heat had ended.

(16) Around Lisbon the second brood began to emerge 16 days later than at home and we cannot explain why that happened. Some adults were on the wing from 6th to 11th May and the emergence ceased as soon as the heat rose suddenly to 85°.

(17) The home-born *brassicae* did not mate in our cages, but a female taken in the country laid about 80 eggs on 8th May (max. 70°, min. 57°) which hatched on the 13th (max. 84°).

(18) Those larvae grew rapidly; however, on the 17th it was 89° and all of them rotted.

II. Records Concerning the Development in Greece.

(19) At Salonika the early brood adults were on the wing from 21st March to 21st April and a female laid many eggs from 11 a.m. to 4 p.m. on 23rd March (60° to 70°). Afterwards the weather was fine for a week but on the 30th it turned cold. In spite of that some eggs hatched in the morning (52°) and the others in the afternoon (48°) of that day.

(20) On 1st April it snowed (min. 31°); the young larvae became dormant and turned active on the 3rd (55°).

(21) From 6th to 9th April the temperature varied daily between 68° and 45°; some larvae moulted in a few hours (record 7), others in about a day (record 8), and the former became bigger than most of the same batch.

(22) On 11th April it was a little hot (79°) with high vapour pressure and the larvae were caught by stupor. On the day following (max. 71°) they became active.

(23) On 20th April it was about 64°, with low vapour pressure, for the whole day, and the larvae were very active.

(24) On 22nd April (about 60° for the whole day) the growing larvae remained active while those which matured became dormant. On the 23rd we put the dormant larvae in direct sunshine (85° to 92°) and they hung up in the afternoon (67° in the shade). After suspension they delayed to pupate until the afternoon of the 24th (70°) taking about 54 hours, since they had become full-fed, to form brown pupae.

(25) Three larvae matured at noon of 23rd April (67°) and hung up at once but later the heat decreased and they remained inactive and formed green pupae, in about 23 hours before noon (70°) of the 24th. Other larvae matured on the 25th and 26th (69° to 74°) and formed bright green pupae in almost 6 hours. On 28th April (max. 74°, min. 50°) seven larvae, which had delayed longer than the others to grow, hung up and pupated in 10 to 12 hours.

(26) At the beginning of May it was on an average max. 63°, min. 46°; on the 9th the heat increased (73°) and the day following some bright green pupae emerged. On the 12th it was 76° and the pupae suspended to produce adults, but afterwards, until the 18th, the maximum varied from 68° to 74°, reaching only once and for a short time to 76°, and all the chrysalids in our cages, even the brown ones, emerged. They had been produced by the eggs laid on March 23rd and had met with the best climatic conditions from 13th to 18th May. In the country, eggs were laid until 21st April (record 19) and the last formed pupae, being altered by 83° heat on 19th May and again by 90° heat on the 27th and 29th, should have remained dormant, as occurred at Lisbon (records 14, 15, 16).

(27) From 10th to 16th May we kept in a large cage, with flowery foodplants and at moderate radiant heat, about a hundred home-born *brassicae* and only two females mated laying very few eggs, which did not hatch. Afterwards we went to collect every day into the country and had no more time to rear larvae.

III. General Conclusions.

(The figures in parentheses refer to the records.)

Eggs.—Some females taken in the country laid upon the plants in our cages more than a hundred eggs on a day (6, 17, 19); others died without laying. The home-born females rarely mated (17, 27) and the few eggs which they laid never hatched. At a medium heat the eggs hatched after nine days; when the heat increased they hatched after either seven or five days (6, 17, 19).*

Growing Larvae.—Below 50° they became dormant and turned active only when the heat increased (20); between 50° and 77° they were more or less able to feed; above 77° they were caught by temporary stupor (22) and above 87° they collapsed (18).

Moulting Larvae.—To change their skin the larvae needed a higher temperature than that at which they were able to feed. At 60° to 83° they changed in a short time and between 55° and 60° they changed at a slower rate (7, 21, 23). Either below 55° or above 83° they became dormant, turning active when the climate became suitable, and moulting in about a day (8, 21, 22). That happened in any moult and the larvae, which most often became dormant, were the last, in any batch, to become full-fed.

Mature Larvae.—The full-grown larvae needed to hang up at a still higher temperature than that at which they were able to moult. Between 63° and 85° they hung up after a more or less short time (11, 25), but if it was below 63° after the larvae matured they became dormant and turned active as soon as the climate was suitable (10, 24).

Suspended Larvae.—When the temperature remained for some time above 65° after the larvae had suspended, those, which had avoided

* For other species of polygenetic (Scudder) butterflies we have remarked that only the adults of the early broods among them mated, while those of the last broods mated, but in mixed relation. In Morocco we had in a cage more than 200 pure-line *Pieris rapae*, L., of the fifth brood and none mated in spite of the fine weather. In Pennsylvania some *Papilio polyxenes*, F., both of the third and fourth broods emerged altogether, in separate cages, at mid-September, 1932, and did not mate; however, they paired when we exchanged the males.

becoming dormant in a mature stage, shed their skin without difficulty and formed green pupae (11, 25); however, if the heat decreased below the point of pupation the suspended larvae remained inactive until the heat increased and they formed either green or brown pupae in accordance with the duration of the inactivity in the suspended stage. Even in the most suitable climatic condition, the larvae which had been weakened by becoming dormant in a mature stage delayed longer to recover and to form brown pupae (3, 10, 24).†

Remarks.—The figures which we record as to be the limits of activity and vitality of the growing, moulting, mature and suspended larvae are not absolute. They refer to caterpillars reared generally in the shade, because when the cages were put in direct sunshine the larvae became very excited above 100°. In the country the matter should be different and more complex from the effects of the radiant heat, wind, humidity, nebulosity and grade of intensity of the vegetation, but, with the poor means at our disposal, we have not been able to study the influence of those factors.

Active Pupae.—The green pupae, formed in a short time, were the earliest to emerge in any of our broods. Sometimes they produced adults in about a fortnight (13, 26).

Dormant Pupae.—The brown pupae, formed with difficulty by the weakened larvae (3, 10, 24) emerged after the green ones when the temperature remained long below 77° (26).

Altered Pupae.—At 75° or 76°, if other climatic factors were favourable, both the active (green) and dormant (brown) pupae delayed to produce adults. The altered green pupae turned active when the climate settled at a suitable range (14) and when the temperature remained long at the optimum range both the green and brown pupae produced adults (26). As the result of a further alteration the brown pupae remained the whole summer in a dormant state and emerged in the fall (14, 15, 26).‡

Adults.—More or less active pupae were formed in any batch together with the dormant ones (10, 11, 12, 24, 25) and the chrysalids which delayed longer to emerge were often altered by the changes of climate (14, 26). The different initial grade of activity of the pupae and the further alterations of some of them produce the scattered emergence of adults of any batch. At Lisbon, in 1933, the early brood of *brassicae* emerged gradually during 68 days (5). Some pupae of the second brood emerged for six days in May, the others delayed emergence until the fall (16). A third brood was able to develop, because in autumn the climate is very lovely in Southern Portugal. Both in 1927 and 1932 we collected there and took some fresh *brassicae* until the beginning of December (1). At Salonika the first brood was on the wing for a month (19); the second for about a fortnight in May (26) and again for almost ten days in September. Afterwards pupae of a third brood were formed but we did not notice their emergence.

† Amongst the caterpillars, which we have reared, those of some *Papilio* and *Pieris brassicae* withstood better a period of remaining dormant. The mature larvae of other butterflies and moths scarcely ever recovered after being dormant about a day.

‡ The dormant (brown) pupae of the *Euchloë* and some *Papilio* never emerged in the year in which they were formed. All those which we have handled went over the winter, and sometimes they emerged after two years.

Control of the Abundance.—The larvae of *brassicae* resisted the cold better than those of the other *Pierinae*, which we have reared. The heat killed all the larvae of the third brood which hatched in May (18) and the species was carried on by the dormant pupae (14, 15, 26). Those which pupated in the open country should have died when, in summer, the temperature of the barren soil reached sometimes 150°, according to the data of the Weather Bureau, and only the chrysalids lying in the most sheltered and moist places were able to resist. In winter the pupae were not injured by the cold either at Lisbon (min. 32°) or Salonika (min. 28°). The climatic factors would not be sufficient to balance the great fertility of *brassicae* and a severe control is effected by the parasites which kill the larvae (4), and by the ants and other insects which eat the pupae.

Some Cumberland Sawflies.

By T. F. MARRINER.

This has no pretension of being regarded as a County List. It is merely an account of such sawflies as I have come across whilst hunting Coleoptera. The area covered in my outings is enclosed by a line from the coast near Maryport through Penrith to the Pennines, along the Northumberland and the Scottish Border lines to the Solway. This is the northern plain of the county. The collecting dates from 1921 to a couple of years ago. During a portion of that period I lived not far from the late Mr. G. B. Routledge and I was his companion and pupil on many a pleasant excursion. It was, indeed, Mr. Routledge who originally advised me to take such insects as bees, sawflies, etc., as I came across them, and he advised me as to where I could get my captures named. To him, to Dr. Perkins and others I owe a deep debt of gratitude for kindly help and encouragement.

When I came to go over my little collection of the Sawflies for the purpose of writing up a list for the *Ent. Record*, I found that, since some of my captures had been named for me, changes had taken place and that some, at any rate, of my names were out of date. None of our local entomologists could help me and I wrote to Mr. Hy. J. Turner pointing out my difficulty, and asking for advice. Mr. Turner has very kindly offered to put me right and I am very grateful to him.

Neurotoma flaviventris, Retz.—This I have come across on one or two occasions and have also bred from larvae taken from the webs where they congregate.

Pamphilius silvarum, Steph.—Fairly common in the Brampton area where, along with

Pamphilius hortorum, Kl.—May be netted on the wing in June.

Pamphilius depressus, Schrnk.—Not so common. Have only taken the ♀.

Cimbex femorata, L.—I have never seen this but include it on account of an interesting old-time record. Mr. T. C. Heysham took it at Carlisle in 1835.

Sirex gigas, L.—I have this from three areas of the county, widely apart. I took one at Heads Nook in the east in 1925, one at Floriston in the north in 1928, and had a specimen sent to me from the vicarage